How Do Choreographers Craft Dance? Designing for a Choreographer-Technology Partnership

Marianela Ciolfi Felice, Sarah Fdili Alaoui, Wendy Mackay

How Do Choreographers Craft Dance? Designing for a Choreographer-Technology Partnership

Marianela Ciolfi Felice
LRI, Univ. Paris-Sud, CNRS, Université Paris-Saclay
91405, Orsay, France
mciolfi@lri.fr

Sarah Fdili Alaoui
LRI, Univ. Paris-Sud, CNRS, Université Paris-Saclay
91405, Orsay, France
saraloui@lri.fr

Wendy E. Mackay
ExSitu, Inria, Université Paris-Saclay
91405, Orsay, France
mackay@lri.fr

ABSTRACT
Choreographers rarely have access to interactive tools that are designed specifically to support their creative process. In order to design for such a technology, we interviewed six contemporary choreographers about their creative practice. We found that even though each process is unique, choreographers represent their ideas by applying a set of operations onto choreographic objects. Throughout different creative phases, choreographers compose by shifting among various degrees of specificity and vary their focal points from dancers to stage, to interaction, to the whole piece. Based on our findings, we present a framework for articulating the higher-level patterns that emerge from these complex and idiosyncratic processes. We then articulate the resulting implications for the design of interactive tools to support the choreographic practice.

Author Keywords
Choreography; Creativity support tools; Technology Design; Dance; Creativity Framework

ACM Classification Keywords
H.5.2 [User Interfaces]: Theory and Models

INTRODUCTION
We are fascinated by the potential for developing a partnership between professional choreographers and technology. However, this presents a major design challenge, since the choreographic process is complex, idiosyncratic, and highly diverse. Choreographers are highly skilled professionals who constantly seek novel forms of creative expression. Each piece is informed by the choreographer's implicit knowlege, which also affects the decision-making process and shapes both individual dance productions and the field of dance as a whole [14]. Choreographers' creative processes are intentionally unique, which makes them reluctant to adopt tools that enforce another choreographer's creative practice. Choreographers do, however, appropriate existing technologies, both physical and digital, adapting them in innovative ways to meet their individual approaches and needs [6].

We are interested in creating technology that is specifically designed to support the early, creative phases of choreography, as well as the evolution of the choreographer's methods over time. Our goal is to allow choreographers to create their own personal languages for expressing ideas on paper, on computers, on stage, in their own bodies and in dancers' bodies. To design such technology, we must first understand how choreographers imagine, create and concretise their ideas, both with and without technology support. This paper presents the results of our study of six professional choreographers. We first review the related work on how choreographers use technology in their practice. We next describe the study, and the specific findings from each choreographer. We then present a framework that summarises common elements across these choreographers, and describe the implications for design. We conclude with directions for future research.

RELATED WORK
Technology can assist choreography by facilitating the generation, real-time interaction, reflection, and annotation of choreographic material (see Fdili Alaoui et al. [1] for a comprehensive review). However, most of these systems are specific to a particular type of dance or choreographic method, making them both idiosyncratic and hard to generalise.

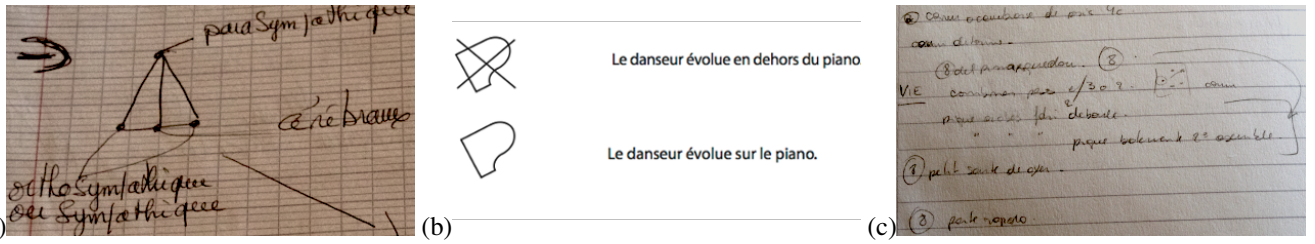
Generation: Dance Forms (formerly known as Life Forms) was the first system to generate new choreographic material. Thecla Schiphorst et al. [17] designed this platform to provide Merce Cunningham with 3D skeletal postures. Carlson et al. created Scuddle [3] as a "defamiliarisation" tool that provokes unfamiliar choices and generates new choreographic material. Church et al. developed the Choreographic Language Agent [4], a sketching environment that encourages choreographers and dancers to explore alternative mappings between visualisations and movement.

Real-time interaction: A number of systems have been designed to partner with performers on stage and for creating digital interactive sets with background visualisations, lighting, and sound (e.g., [15]).

Reflection: The Entity project [8] – with the participation of choreographer Wayne McGregor – involved the design of adaptive software agents to solve choreographic problems,

Marianela Ciolfi Felice, Sarah Fdili Alaoui, Wendy E. Mackay. How do choreographers craft dance? Designing for a choreographer-technology partnership. In *Proceedings of the 3rd International Symposium on Movement and Computing.*

ISBN 978-1-4503-4307-7/16/07.
http://dx.doi.org/10.1145/2948910.2948941



(a) (b) (c)

Figure 1. High-level choreographic object (Myriam Gourfink) (a). Spatial constraint for movement, from *"Collision hétérogène"* (Amandine Bajou) (b). Dance sequence for a group of dancers (Fernanda García) (c).

augment creativity, and establish principles of choreographic thinking. Other reflective technologies, e.g., [16]), reveal choreographic structures and patterns through visualisation of movement data.

Annotation: The goal of the annotation software developed by the Transmedia Knowledge Base for contemporary dance project [2] with the choreographer Rui Horta, is to assist the choreographer's creative process.

Although many systems attempt to address the choreographic practice, choreographers still lack access to advanced, general-purpose software tools that support the early phase of the creative process, before ideas have been fully developed. This is influenced by the high variability in materials and modern choreographic methods, as well as the scarcity of theoretical frameworks grounded in real-world practice. We argue that creativity-support tools should take advantage of existing frameworks, such as Shneiderman's [18], which suggests that tools should facilitate exploratory search, support generation of multiple alternatives, enable collaboration, provide a rich history and allow users to revert to previous states as needed. The first step towards accomplishing such a partnership between choreography and technology is to interview choreographers and build upon the higher-level commonalities in their implicit, complex, and highly creative craftsmanship.

INTERVIEWING CHOREOGRAPHERS

We interviewed six professional choreographers about their choreographic practices. Our goal is to understand the elements they manipulate as they create a piece and how these elements evolve during the choreographic process.

Participants: Six professional choreographers (five women; ages 24-47) participated in the study. Five create contemporary dance pieces; the other choreographs tango pieces from a contemporary dance perspective. They have between 2 and 20 years of experience.

Procedure: Each interview lasted for approximately one hour. We asked each participant to choose a recent piece that they had choreographed, either current or complete, and to describe their creation process, step by step. We asked them to show us the artefacts they used to explore or record ideas, including notebooks, video, and digital files. We then probed for specific stories, sparked by their design artefacts, in order to help them provide a grounded reconstruction of the details. These stories helped us to understand what they actually did, rather than how the process "should" work, and provided us with rich, comparable data about their design challenges and decisions.

Data collection: We recorded audio and took hand-written notes during the interviews. We also photographed the choreographers' design artefacts. In some cases, we recorded video as they performed choreographic fragments from their stories.

Data analysis: We anonymised the interview data and refer to participants as P1-P6. However, we credit the choreographer when we present images of their intellectual property, specifically their personal notes, scores, and choreographic notation. We used a grounded theory approach [5] to analyse the stories. We first selected examples that formed natural categories, looking for higher-level concepts and relationships that emerged from the details. We mapped each story to one or more category. We iterated this classification until we identified six primary categories: *choreographic objects*, *creative phases*, *representations*, *operations*, *specificity*, and *focal points*.

UNDERSTANDING CHOREOGRAPHERS' CREATIVE PROCESS

All participants chose pieces with a contemporary dance approach, with diverse contexts and initial constraints. P1 created a tango that is strongly influenced by contemporary dance elements. Although tangos are typically performed in pairs, this dance involves a solo performer, who interacts with a musician on stage. P2 choreographed a piece for two dancers who interact with a piano by dancing on it and generate sound by hitting its surface. P3 designed a piece for a group of dancers whose bodies represent stone fragments that evolve in space and time. A key challenge for P3 was to make the work fit within a larger performance that included choreographies based on several different dance styles. P4 created a dance for a play that was constrained by the script and the choice of traditional children's games. P5 choreographed a piece for over 100 non-dancers within a public installation. P6 designed a piece, inspired by yoga and meditation techniques, that explores how body and mental states can generate movement, sustained in time. Only two choreographers (P3 and P5) worked with predefined music; the others collaborated with a music composer. We identified six categories that emerged from the participants' creative processes.

Choreographic Objects

Choreographic objects represent choreographic ideas that are manipulated throughout the entire process. Choreographers formalise them at various levels of abstraction and detail, at

times in their own minds, in the dancers' bodies and memories, or captured via paper, video or other support tools. For example, P6 began a piece inspired by the concept of 'beatitude', and P1 transformed the traditional two-person format of a tango into a solo. Each used a different strategy to explore the intial choreographic object: P6 defined very specific constraints for determining how the movement would develop, whereas P1 improvised by pretending to dance with an imaginary body in the room. Eventually, P6 abandoned the idea of beatitude but continued working under the initial constraints to generate the score of the piece. P1 added other guidelines to generate movement material and compose sequences, typically linked with metaphors and feelings. Even though the details of each strategy varied greatly, we found that all choreographers began with an initial idea or set of ideas, which generated the elements that formed the final choreographic piece, similar to [17]. Figure 1 shows representations of several types of choreographic objects: Inspirational symbols and high-level concepts (Fig. 1a), constraints (Fig. 1b), and dance sequences (Fig. 1c).

One of the central points in *Synchronous Objects* [16] – a series of online interactive animations based on the choreographer William Forsythe's *One flat thing, reproduced* – was how choreographic ideas can be expressed, and exist, in durable media other than the body. For Forsythe, choreographic ideas in the form of 'choreographic objects' encourage choreographic thinking, rather than replacing the body [20]. deLahunta and Pascual talk about 'pre-choreographic elements' [7], referring to a 'pre-phase of choreography', in which content is created and tested but still not selected or ordered. Their work focuses on "specific (moving) ideas or concepts" that appear consistently throughout the work.

We found that a few (2/6) participants articulate their work using well-known dance vocabulary, such as postures, phrases, sequences, scenes. The others occasionally use these terms, but more often focus on the piece as a continuous sequence of movement with identifiable 'moments', 'states', or even 'colours', rather than discrete parts with a beginning and an end.

Choreographers sometimes use temporal references to refer to their choreographic objects: P4 talks about a *"sequence that goes from beats 1 to 16"*, while others use spatial references: P3 refers to *"the part in which the dancers are in a round"*. Some choreographers name their objects with criteria ranging from distinctive visual characteristics: P1 had a *'duck feet posture'*, metaphors: P1 dances a *'wind sequence'* as if being pushed by wind, feelings: P4 choreographs a *'moment of hate'*, to more complex concepts, such as song titles that remind them of the movements in the choreographic object.

We collected many examples of choreographic objects that are actually the final outcome of the composition, without constituting the choreographic piece itself. In fact, two participants (P2 and P6) use a 'constraints-based composition' approach: they do not formalise movement directly, but instead specify rules that govern it, allowing the performers to create – or discover – concrete movements by exploring the space defined by these constraints.

Creative Phases

We found that choreographers' creative processes, despite being highly diverse and personal, pass through a series of creative phases that we call: *preparation* – before working with the dancers –, *studio* – interacting with the dancers and the support materials –, *performance* – during the shows –, *reflection* – after a studio session or a performance –, and *out of context* – stories not related with their current project (Fig. 2). Regarding this last phase, we observed that for most (5/6) participants it is important to annotate ideas even when they are not directly related to their current projects, because they plan to develop them in the future, because they were inspired while doing something else, or because they feel the need to journal their experience.

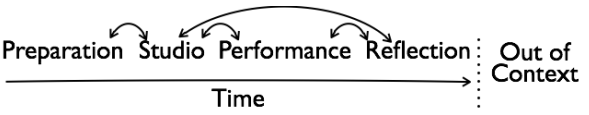


Figure 2. Choreographers' creative phases with iteration paths.

Given that choreographic composition is an iterative and interactive process [17], it is not surprising that the limits between these phases are not always clear. Only two participants spontaneously spoke of well-defined phases; the others articulated them in a more fluid or implicit way. Choreographers might, for example, loop several times over *preparation-studio-reflection* before the *première*, or they may work on different phases in parallel for different parts or aspects of the piece. P1 and P2, for example, both started with a preparation stage that included the search for a movement and sound vocabulary. P1 created the initial structure of the piece, and P2 tested the generated movement material in her own body. They both then transitioned into a long studio phase working with the performers, followed by successive reflection phases after rehearsals, including collaboration whith an 'external eye' who would correct details or propose changes. Shortly before the *première*, P1 repeated the whole process *"in a micro scale"*.

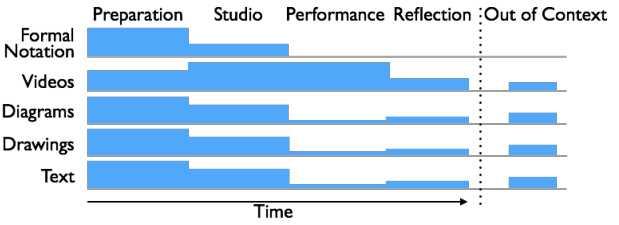


Figure 3. General use of representations along the creative phases.

Representations

All of the participants represent their choreographic objects with *drawings*, *text*, *diagrams*, and *video*. Half (3/6) of them also use some type of *formal notation*. Fig. 3 shows the general use of these representations along the creative phases. Drawings, text and diagrams are created primarily during the preparation phase, modified extensively during or after rehearsals, and occasionally when an idea occurs outside of the

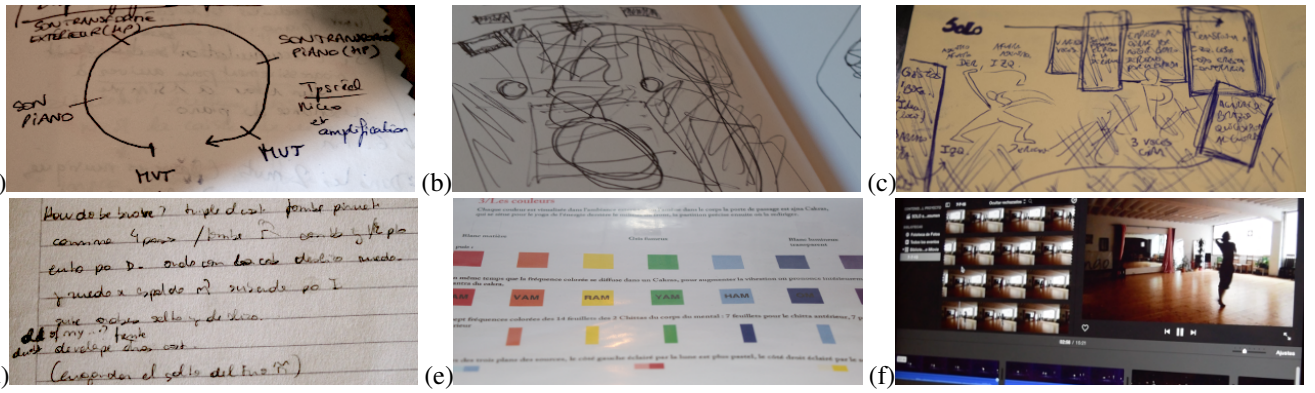


Figure 4. Examples of representations: Diagram of sound transformation along the piece (Amandine Bajou -P2-) (a). Collaborative schematic drawing with music composer (Amandine Bajou) (b). 'Vignettes' of movement in notebook (Matías Tripodi -P1-) (c). Very subtle in-line drawings (Fernanda García -P3-) (e). Printed diagram of flow of chakras (Myriam Gourfink -P6-) (d). Video editing in *iMovie* (Matías Tripodi) (e).

context of the project. They are rarely referred to during the performance or when reflecting upon the piece. For example, P6 started by writing text from inspirational readings in yoga and meditation, making symbolic drawings and referencing books. Interestingly, she maintained the mapping between this material and the score only in her mind. For her, the creative decisions were *'evident'* (P6). P2 made a diagram to represent how sound is transformed in relation to movement (Fig. 4a). She also created schematic collaborative drawings with the composer, during a discussion in which they drew at the same time (Fig. 4a). P1 drew *"rough drafts of human figures"*, with text directions, e.g., *"do it several times"*. He organised the figures in *'vignettes'* in his notebook, using arrows to guide *"the temporal succession"* (Fig. 4c). For him, these vignettes provide *"a sequence of frames that let [him] save an idea"* (P1). P3 drew very subtle drawings in line with the text (Fig. 4d). For almost all the examples we collected, drawings were augmented with text.

Half (3/6) the participants write only keywords or very short sentences to record their choreographic objects. Surprisingly, the participants who use formal notation write long texts at the beginning, either to capture inspiration (P1, P6), or to work out ideas and *"avoid including text in the final score"* (P2). These three choreographers also create digital documents to support their creative process. P1 keeps a text file with columns for scenes, lights and transitions. P2 and P6 create digital versions of their scores with graphical editing tools (Fig. 6a and b). P6 also prepares diagrams that represent higher level ideas, such as the intended flow of dancers' chakras (Fig. 4e). P6 uses a legacy application which allows her to reuse previous work, but this requires her to keep an outdated computer, with an outdated operating system, in order to run it.

All participants capture video in the studio and during performances; some (2/6) film themselves while exploring movements during preparation. They watch the videos alone or with the dancers as they reflect upon the piece. P4, in addition, shares the videos with the dancers within a social network group. P6 solved a choreographic problem by watching a video from a rehearsal at a slow speed. P6 and P1 edited video with *iMovie* (Fig. 4f).

None of the participants use a pure formal notation system. P2 and P6 adapted Laban notation for their own needs, augmenting it with symbols they consider more suitable for composition (Fig. 6a and b). P1 recently developed his own notation for tango choreographies (Fig. 6c).

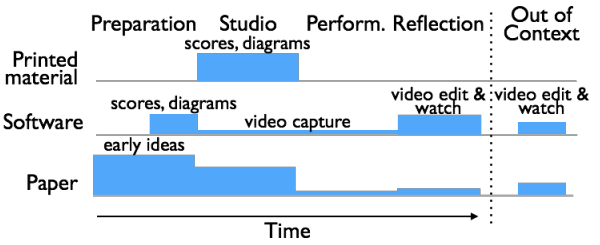


Figure 5. Supports generally used for representations along the creative phases.

All participants use paper to represent their ideas (Fig. 5). P1 told us: *"through paper I can have a very personal register of the piece"*; P4 mentioned that she *"needs the paper"*; P2 summarised the creative process as *"a constant back and forth between the paper, the ideas and my body"* (P2). Some participants appropriate their notebooks, for example P5 uses temporal colour codings, and leaves a series of graphical 'traces' to link pages together.

When probing for changes, we found several examples of non-recorded decisions that were memorised by the choreographer, or kept in the dancers' bodies and memories. We also collected stories that involve printing a score of the piece, making multiple iterations of handwritten corrections on the printed surface as the rehearsals went by, and only updating the digital version before printing the final score.

Operations

Operations are actions applied to choreographic objects in order to build a piece. They are key points where the choreographer's skills come into play, resulting in new choreographic objects or refined versions of the existing. We identified four categories that are present in at least one story from each participant: *transforming*, *structuring*, *abstracting*, and *transmitting* (Fig. 7).

Transforming implies modifying existing choreographic objects, either to make them evolve or to create new ones. P2

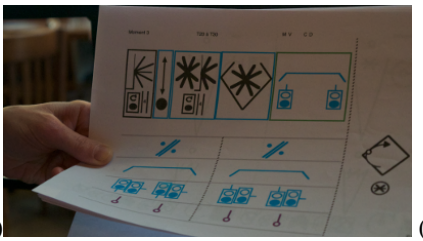
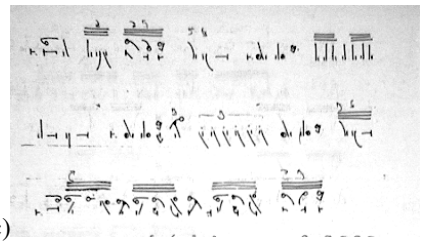
(a)  (b)  (c) 

Figure 6. Digital score from *"Collision hétérogène"* (Amandine Bajou) (a). Myriam Gourfink's printed score (b). Matías Tripodi's tango notation (c).

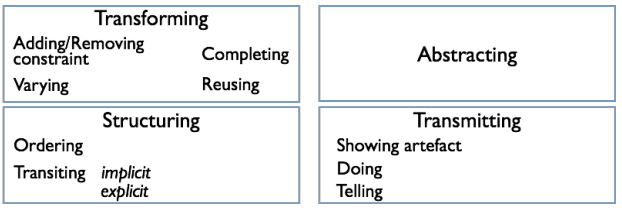


Figure 7. Types of operations on choreographic objects.

told us that she and the composer authorised themselves to generate *"a variety of movements, a maximum number of possibilities, to maybe come back to one of the previous"*. Transforming can be achieved by *adding or removing constraints*. For example, P1 told the interpreter: *"now do it as if you were in a cold room"* (metaphoric constraint), whereas P6 removed an orientation constraint imposed on the dancers, in order to solve a choreographic problem. Another approach is *varying choreographic objects* through actions such as changing the body parts involved, mirroring, inverting, or changing the speed. Interestingly, P1 applies all these strategies when composing or teaching dance, but he also uses the last three when editing video segments after improvisation sessions. Another method of transforming choreographic objects is to *reuse* them, for example, through repetition. P5 explicitly refers to previous choreographic objects in her compositions: *"Final sequence just like in Intro"*. Choreographers also transform by *completing* a choreographic object, which entails defining additional aspects and details or specifying existing details. For example, P1 stated: *"the movement came to me and I drew it, and as I practiced it, and thought about it, I defined other things to complete it"*. P6 watched videos of the rehearsals with the dancers, in order to fix elements of a sequence.

Structuring refers to combining choreographic objects to give structure to the piece. P1 created a 'draft of movements', a list of early ideas without a defined temporal succession, that he later ordered to structure the piece. P6 drew a digital diagram with the 'key situations', highlighting the group of dancers' pathways. P5 defined 'modules' that the dancers could combine in time under certain rules, resulting in a different structure every performance. The most frequent types of structuring in the stories were *ordering* (putting the choreographic objects in a certain temporal order or defining the rules to do so) and *transiting*. *Transiting* operations are associated with the way the choreographer conceives transitions between choreographic objects. For some choreographers, transitions are as important as the choreographic objects, and they spend considerable effort in defining and transmitting them to dancers and collaborators. P1, for example, keeps a shared digital document ('the script') that contains very detailed transitions. We noticed two main kinds of transiting: *implicit* (the piece is seen as a sequence of choreographic objects in which transitions are indistinguishable; for example, P3 identifies 'moments' such as 'calm' and P4 'states', e.g., 'love'), and *explicit* (the piece is composed of choreographic objects and explicit transitions between them, as in P1's story, where he keeps a list of 'scenes' and 'transitions', specifying how transitions are triggered, what should the dancers do, etc.).

Abstracting a choreographic object represents the act of 'zooming out' from it – displaying less detail to see the big picture, to get a global sense of the choreographic object and its surroundings, to visualise its relationships, transmit it, or analyse it for decision making. This is a fundamental operation that we detected in all participants' creative process multiple times. For example, P2 spoke to the composer about a choreographic object, and drew *"only the elements needed to recognise it"* (P2). They also created a *"summary of sections"* to *"visualise the piece globally"* (P2) . P1 emphasises the importance of specifying *"only a few parameters that describe movement"* for composing and transmitting choreographic objects. In her notebook, P5 writes with different pen colours *"the big thing"* and *"the details"*. She teaches *"what it has to be done: the dancers' coordination"*, leaving *"details such as transitions"* (P5) to a later stage in the process. She uses her body's shadow on the wall to check how a movement looks: *"the mirror gives too much detail I am not interested in seeing"* (P5).

Transmitting a choreographic object to dancers and collaborators is achieved in the collected stories via *showing an artefact* (mostly scores and videos), *doing* (actually performing the movements), *telling* (explaining the choreographic object verbally), or combinations of these strategies. We noticed that participants tend to transmit choreographic objects by showing an artefact or by doing the movements when they already have a defined idea that they want to teach, while they turn to verbal indications when the idea is still vague or open. P1, for example, gave the interpreter an indication *"that was not enough at all, just a rough draft to test the creativity in the answer"*. We consider in the transmitting category the examples in which the choreographers try out a choreographic object with their own bodies, since they are transmitting it from one cognitive level (mental) to another (corporal), usually with the purpose of making movement decisions. Typically, when applying a transformation, the participants assess the results by performing the movements themselves, but some of them (P1 and P2) by also discussing with a collaborator, who they

call an 'external eye'. P4 only keeps a newly generated movement *"if it feels comfortable and organic, if it is real"* in her body. For P2: *"Sometimes a movement would not be effective or would not answer to our intentions, but we tried to define a space as broad as possible"*.

Specificity

Like music composers [9], choreographers define their choreographic objects with various degrees of specificity. For example, P5 started by writing goals – a list of sensations to convey through the piece –, rather than *"predesigned sequences"* (P5), and P6 collected texts about inspiring topics, and defined the global idea for the piece, without any explicit connection to concrete movements. Most (5/6) participants gave guidelines to dancers to generate movement material. P2 created a score precisely defining aspects such as the body zone involved, the type of movement, the orientation in space, while leaving the order of the choreographic objects and their concrete trajectories up to the performers' choice. Interestingly, P3 designed many sequences using a technical vocabulary in a precise temporal way, but only retained meaningful 'moments' in her memory.

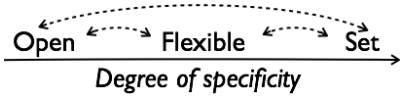


Figure 8. Degree of specificity of choreographic objects.

As we see in these stories, choreographers constrain certain aspects of their choreographic objects and operations, while leaving others to the dancers' interpretation. In this continuum of specificity (Fig. 8), a choreographic object can be characterised as *open* (e.g., P6's global idea for the piece), *flexible* (e.g., giving guidelines) or *set* (e.g., P3's concrete sequences). We do not imply that in a *set* choreographic object every aspect of the movement is completely described, nor that it is predetermined or predictable, given the interpretative nature of some approaches of dance, and bearing in mind the great richness of each individual body's expression and signature.

The degree of specificity changes along the creative phases. Choreographers typically start by defining their ideas in an open way during preparation, and as they iterate, they increasingly constrain these ideas by operating on them. These results are compatible with Garcia et al.'s study of contemporary music composers [11]. However, some choreographers – for example, P6 – define some choreographic objects very specifically from the beginning. Participants often leave some choreographic objects open (or flexible) throughout the whole process: 'open' does not necessarily mean 'unfinished', it can be purposely 'incomplete'. On the other hand, choreographic objects that code rules and constraints instead of movements or gestures, can be precisely set and yet the dancer's movements can actually be more improvised than the resulting from a flexible constraint upon movement. Even though the shift in specificity is typically towards more specific choreographic objects, the other direction can be taken, for example, when solving choreographic problems by removing constraints, or when stepping back to visualise elements from a more abstract perspective. There is a fascinating interplay between the number of constraints applied, the nature of the choreographic object or operation on which they are applied, and how much the resulting movement is fixed.

Representations vary with the degree of specificity. Open choreographic objects are typically described using text and sometimes drawings, set ones seem more compatible with formal notation and video, and flexible ones tend to present a combination. Despite these trends, choreographers decide when and how to use each representation according to their needs.

Focal Points

We found that choreographers compose their work by shifting between different levels of abstraction – in depth –, but also different *focal points* – in width. Choreographers define choreographic objects with the attention in the piece as a *whole*, in the *stage*, in a particular *dancer*, in an *interaction* (between dancers, with an object, with the stage, with an idea), and in *temporal patterns*.

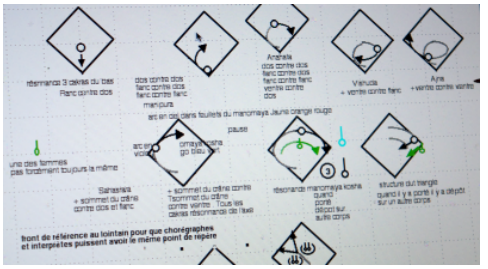


Figure 9. Focal point in the stage: Floorplan with group of dancers' pathways (Myriam Gourfink).

For example, P6's scores have 'movement notions', since she is *"not interested in describing movement ... [but] in giving the idea for the piece"* (focal point in the *whole*). More than half (4/6) of the participants draw floorplans where each dancer or group of dancers is represented by a circle (or a cross), and their pathways are indicated with lines, as shown in Fig. 9 (focal point: *stage*). P1 designed movements based on the limitations of a bandoneon to produce sound (*interaction* with an object), and P4 wrote a sequence that two dancers should perform mirroring each other (*interaction* between dancers). More than half (4/6) of the participants composed at least one sequence for a particular dancer (*dancer*). P2 drew a 'temporal shape' diagram of the piece in order to agree on the 'global intensity' with the composer (*temporal pattern*).

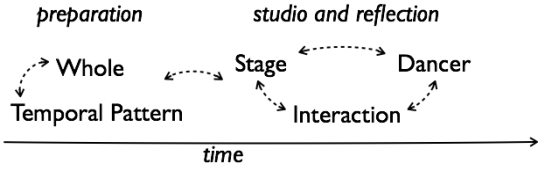


Figure 10. Focal points along the creative phases.

Focal points are shifted along the creative phases (Fig. 10). In the preparation phase choreographers usually start defining choreographic objects about the piece as a whole and some global temporal patterns, refined later in the studio by focusing in the stage, interactions, and eventually a particular

dancer. However, choreographers might decide to start from any focal point and switch back and forth in width as the process evolves.

Choreographers rely on their choreographic skills, intuition and memory to map the elements in different focal points. For example, most (3/4) of participants who draw floorplans keep separate notes about the movements that individual dancers will make to concretise their pathway, but we have not seen any annotated mapping between these documents.

Different representations appear more suitable for different focal points. For example, drawings of floorplans are frequently used to represent choreographic objects focused in the stage, text to describe ideas about the piece as a whole (or to complement drawings), videos to capture the interaction between dancers, and formal notation to specify the sequence for one ore more performers.

FRAMING CHOREOGRAPHERS' CREATIVE PROCESS

The above six categories form a framework that captures the key elements of choreographers' design practices. *Choreographic objects* serve as the *focal point*, with a certain degree of *specificity*. They are expressed via different *representations*, and evolve through several *creative phases* as the choreographer applies *operations*. The focal point may refer to the whole piece, the stage, a dancer, an interaction or a temporal pattern, and may be defined in an open, flexible or set way. Choreographic objects can be represented with combinations of drawings, text, diagrams, video or formal notation, and, for example, created in a preparation phase, transmitted in the studio, and transformed multiple times during these phases or in a later stage of reflection.

Choreographers create, edit, and transmit choreographic objects and operations. They rely on artefacts (drawings, videos, etc.) to complement corporal and verbal explanations. But why do they record so few changes when they compose a piece? Why does a considerable part of their decision-making process remain implicit? One possible reason is the lack of tools for recording, accessing, and manipulating their material without requiring excessive time or effort. P1 felt that some choreographic problems could benefit from technology, particularly when communicating 'conditions' and transitions to the dancers, and to transmit specific modifications of the piece. He also expressed the need to visualise the elements of a composition and to *"try different orders"*. In addition, all the participants had trouble remembering the meaning of certain notes or drawings, stating that during the composition process they did instantly. Participants who use some type of formal notation, still prepare diagrams or drawings and textual indications to complement their scores. These findings suggest that current formal notation is not sufficient to fully represent choreographers' ideas, even after they make personal adaptations to the notation system.

Choreographers constantly shift across levels, both in depth and in width, during the composition process (Fig. 11). They play with the specificity of the choreographic objects (depth) by applying the operations in the categories of abstracting and completing. They also switch the focal points (width).

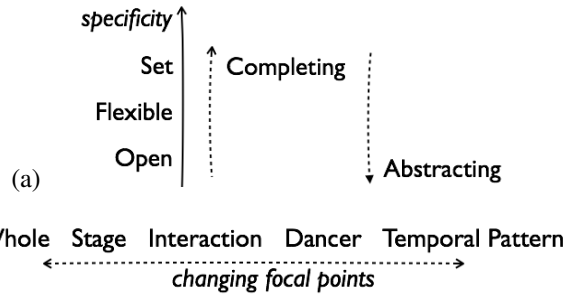


Figure 11. Shift in depth (a) and in width (b).

Kirsh [12, 13] found that choreographers' decision-making process is distributed across many elements, such as their – and the dancers'– knowledge, individual and cultural influences, skills, and the environment. Our findings reflect this, especially in the interaction among dancers as they explore movement possibilities, collaboratively make decisions, and share their memories of the piece. Choreography is a key example of situated action [19] – choreographers may plan their composition in advance, but the environment forces them to adapt these plans and take alternative paths.

IMPLICATIONS FOR DESIGN

We identify the following implications for the design of interactive tools to support the choreographic creative process, based on the findings represented in the framework:

Interactivity: Create interactive ways to visualise and manipulate choreographic ideas and operations that can be shared with dancers and collaborators.

Knowledge availability: Leverage the accumulated knowledge about the piece, making it not only easy to retrieve, but also easy to (re)discover and reuse (including out-of-context ideas).

Shifting: Track links between the artefacts produced in each level of abstraction or focal point; and support strategies for recording incomplete choreographic ideas and operations.

Distributed cognition: Support choreographic knowledge distribution and collaborative decision-making.

Situated action: Take into account the setting in which the tool will be used, according to the creative phases, e.g., in the studio users might split their attention between the tool and the dancers, whereas during reflection they may be in a more calm environment.

CONCLUSIONS AND FUTURE WORK

We conducted story-centred interviews with six choreographers, who guided us step-by-step in the creation process of a recent piece they choreographed. We identified six categories that reveal emerging patterns from the data we collected. We created a framework that articulates these categories and that captures key elements in the choreographic processes. From our framework, we extracted various implications for the design of interactive tools that support the choreographers' creative practice. To tackle this challenge, we plan to investigate the use of interactive paper, which has been used successfully to support music composition [10]. Our interviews indicated

that while some choreographers resist screen-based interaction, all include paper as an essential part of their creative process. Paper is a flexible, portable support that allows choreographers to rapidly generate diverse representations of their ideas, in a variety of settings. Our goal is to augment rather than replace these choreographers' existing creative practices with paper, enabling them to personalise and appropriate the technology to suit their personal preferences and needs.

Creating a framework for such a dynamic field as dance, which constantly tests and breaks its own habits and rules, is challenging. Choreographers not only have heterogeneous creative processes that are thus very hard to generalise, but also work in isolation from other choreographers, in spite of how close their collaboration can be with other artists such as music composers. There is an inherent beauty and uniqueness in this field that might resist, at a first sight, attempts of characterising or extracting common patterns from it. However, we believe it is fundamental to build upon its knowledge in order to preserve the art of choreography composition, and it is by establishing such framework that we can begin to design interactive tools that recognise and preserve the uniqueness of each artist, leveraging upon higher-level commonalities.

ACKNOWLEDGEMENTS

This work was partly funded by the ERC Advanced Grant #321135 CREATIV.

REFERENCES

1. Alaoui, S. F., Carlson, K., and Schiphorst, T. Choreography as mediated through compositional tools for movement: Constructing a historical perspective. In *Proceedings of the 2014 International Workshop on Movement and Computing*, ACM (2014), 1.

2. Cabral, D., Carvalho, U., Silva, J. a., Valente, J. a., Fernandes, C., and Correia, N. Multimodal video annotation for contemporary dance creation. In *CHI '11 Extended Abstracts on Human Factors in Computing Systems*, CHI EA '11, ACM (New York, NY, USA, 2011), 2293–2298.

3. Carlson, K., Schiphorst, T., and Pasquier, P. Scuddle: Generating movement catalysts for computer-aided choreography. In *Proceedings of the Second International Conference on Computational Creativity* (2011), 123–128.

4. Church, L., Rothwell, N., Downie, M., delahunta, S., and Blackwell, A. F. Sketching by programming in the choreographic language agent. In *Proceedings of the Psychology of Programming Interest Group Annual Conference.(PPIG 2012)* (2012), 163–174.

5. Corbin, J., and Strauss, A. *Basics of qualitative research: Techniques and procedures for developing grounded theory*. Sage publications, 2014.

6. delaHunta, S., McGregor, W., and Blackwell, A. Transactables. *Performance Research 9*, 2 (2004), 67–72.

7. delaHunta, S., and Pascual, B. B. Pre-choreographic elements: Scott delahunta in conversation with bertha bermúdez. *International journal of performance arts and digital media 9*, 1 (2013), 52–60.

8. delaHunta, S., and Shaw, N. Z. Choreographic resources agents, archives, scores and installations. *Performance Research 13*, 1 (2008), 131–133.

9. Garcia, J. *Supporting music composition with interactive paper*. PhD thesis, Université Paris Sud-Paris XI, 2014.

10. Garcia, J., Tsandilas, T., Agon, C., and Mackay, W. Interactive paper substrates to support musical creation. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '12, ACM (New York, NY, USA, 2012), 1825–1828.

11. Garcia, J., Tsandilas, T., Agon, C., and Mackay, W. E. Structured observation with polyphony: a multifaceted tool for studying music composition. In *Proceedings of the 2014 conference on Designing interactive systems*, ACM (2014), 199–208.

12. Hollan, J., Hutchins, E., and Kirsh, D. Distributed cognition: Toward a new foundation for human-computer interaction research. *ACM Trans. Comput.-Hum. Interact. 7*, 2 (June 2000), 174–196.

13. Kirsh, D. Creative cognition in choreography. *Proceedings of 2nd International Conference on Computational Creativity* (2011).

14. Lynne Anne Blom, L. T. C. *The Intimate Act of Choreography*, first edition ed. University of Pittsburgh Press, 1982.

15. Meador, W. S., Rogers, T. J., O'Neal, K., Kurt, E., and Cunningham, C. Mixing dance realities: collaborative development of live-motion capture in a performing arts environment. *Computers in Entertainment (CIE) 2*, 2 (2004), 12–12.

16. Palazzi, M., and Shaw, N. Z. Synchronous objects for one flat thing, reproduced. In *SIGGRAPH 2009: Talks*, SIGGRAPH '09, ACM (New York, NY, USA, 2009), 2:1–2:1.

17. Schiphorst, T., Calvert, T., Lee, C., Welman, C., and Gaudet, S. Tools for interaction with the creative process of composition. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM (1990), 167–174.

18. Shneiderman, B. Creativity support tools: Accelerating discovery and innovation. *Communications of the ACM 50*, 12 (2007), 20–32.

19. Suchman, L. A. *Plans and situated actions: the problem of human-machine communication*. Cambridge university press, 1987.

20. Weisbeck, M., and Forsythe, W. *William Forsythe: Suspense*. Jrp Ringier, 2008.